Lake Erie Workshop
SOLEC 2004

Physical Integrity of Lake Erie
Landscapes, Watersheds, and Hydrology

Physical Integrity – Physical structure, connectivity, and processes that "…maintain a balanced, integrated, and adaptive system capable of sustaining all components and interactions (structure and function) in an organized manner."

1. **How has the physical integrity of Lake Erie been impaired?**
   - **Watersheds**
   - **Tributaries**
   - **Estuaries/River mouths**
   - **Coastal Wetlands**
   - **Nearshore (< 10m water depth, < 5m in Western Basin)**
   - **Open Lake**

Loss of permeability due to development; loss of wetlands; loss of riparian zones, channeling and culverting; ditch maintenance, hardening of lake and stream shorelines; navigation channels, loss of estuarine wetlands, altered hydroperiod, coastal wetlands no longer connected to lake, no seasonal variation in flows, increased erosion, natural substrate buried in sediment; no deltas – hard straight shorelines; sand in littoral zone lost and littoral transport altered; change in light regimen (decreased turbidity); altered base flows in streams; altered thermal regime.

Watersheds – change in hydrology and hydrogeology
Tributaries – change in channel morphology, change in streampower, change in substrate transport, change in substrate structure
Estuaries/River mouths – change in channel morphology, change in substrate structure, change in light
Coastal Wetlands – change in water levels, change in energy, change in hydrology
Nearshore – change in channel morphology, change in substrate structure, change in light
Open Lake – change in substrate, change in light

Watersheds – housing/city/ind. development, the drainage, ditching, loss of wetlands, riparian areas
Tributaries – channelization, loss of adjacent wetlands, destruction of riparian areas, dams
Estuaries/River mouths – filling, straightening, marine development, sedimentation
Coastal Wetlands – filling, erosion, high lake levels, diking, farming, upland borders stopping migration, invasive species (plants), sediments
Nearshore – sand mining, hardening shorelines, development, invasive species, jetties

Open Lake – enlarging Detroit river shipping channel, sand mining, chemical contamination, open lake dredge spoil

- High flows – missing because of regulation therefore no flushing of sediment
- Artificial hydrograph – from dams
- Draining and filling wetlands; diking of wetlands
- Sedimentation increase
- Zebra mussels – shoreline
- Anoxia of open water
- Water levels – shoreline protection
- Geology/groundwater recharge areas having substrate change to more impervious
- Ditching/channelization/geomorphology of streams
- Tile drainage
- Reservoirs
- Nutrients – shift in nearshore communities

- Impermeable cover
- Temperature of runoff water will be higher
- More sediment input – tributary plume from [?]
- Higher flow and increased erosion
- Human response to hardened shoreline
- Navigational dredging – stratification, dissolved O_2 problems, changes flow in lower 4-5 miles in the lower stretch of the tributaries
- Deforestation
- Barriers/dams, control structures
- Lower water table/ground water withdrawals
- Water levels

Lack of flushing	Sedimentation (sediment transport)
Occasional flushing	Attend substrate
Dams and obstructions	Water clarity
Impervious cover	O_2 problem
Deforestation	Shoreline hardening
Wetland destruction/disruption	Ditching/channelization

- Draining and filling of wetlands and diking wetlands
- Loss of land cover
- Loss of sediment transport – starvation of sands from shorelines
- Zebra mussels changing sediment characteristics
- Anoxia
- Daming tributaries
- Channelization of tributaries

Regulation of flows and reservoirs (dams – “disconnect the physical system”); lack of flow/flushing stream flashiness; increased urbanization/sprawl, increased impervious surface, physical loss – especially wetlands, upland erosion = sedimentation in estuaries, sediment transport both in rivers and along coast, shoreline development, diking wetlands, zebra mussel reefs, accumulation of shells, anoxia/dead zone, shoreline protection leading to undermining of structures with water level fluctuations, artificial structures – artificial reefs – positive? Disconnect of stream from groundwater, ditching, dredging, channelizing, tile drainage. Flow levels – range of variability.

- Lack of riparian zones and buffer
- No high flows to flush out contaminants
- Natural flow is controlled and regulated
- Urbanization and paving (land use), large physical changes
- Wetland loss resulting in physical change
- Introduction of exotics (zebra mussel shells accumulation)
- Low oxygen zone
- Habitat loss and degradation
- Structure suspending lake shore currents
- Alterations to land (aggregate operations) change flow patterns therefore physical integrity
- Channelization and ditching tributaries
- Reservoirs and dams

Watersheds – temperature and rapid drainage
Tributaries – rapid runoff = erosion
Estuaries/River mouths – erosion = deposition of silt and temperature increases
Coastal Wetlands – temperature increase
Nearshore –greater difference in temperature, turbidity and O_2 levels
Open Lake

- Watershed; deforestation – urban impervious surface, agriculture

H_2O:

1. Temperature increase
2. Rapidly enters streams
3. Lower reaches dredged; water fast tracked to lake. Creates difference with surface layers and deep water for temperature and turbidity = dead zone of O_2

Physical integrity – habitat, hydrology, landscape, substrate, water mass

- High sediment loads
- Less connectivity
- Loss of natural heritage features
- Altered currents
- Disturbance of sediment

- Regulated flows, lack of flushing flows, dams
- Artificial hydrograph due to land use
- Increases in impervious surfaces/urbanization changes flow regimes and groundwater regimes
- Shoreline development and alteration/cottage development
- Shoreline alteration due to zebra mussels
- Water levels – lack of fluctuation
- Thermal pollution industry?
- Change of flow paths from groundwater to surface water due to change in landscape e.g. paving
- Drainage – tile drainage
- Lack of natural geomorphology shape and structure
- Reservoirs that change d/s processes streams with no pools and riffles

Watersheds – change of vegetation, groundwater withdrawal, impervious surface,
Tributaries – channelization, destruction of natural flood planes and daming, loss of connectivity
Estuaries/River mouths – dredging, filling, []
Coastal Wetlands – [], filling, [], sedimentation
Nearshore – invasive species
Open Lake – natural loading

2. **What are the stressors causing these impairments?**
    - **Landscapes/watersheds**
    - **Hydrology**
    - **Other**

Loss of natural areas by development (residential/commercial/industrial); loss of riparian buffers and wetlands; inadequate stormwater management; shoreline hardening; ditch maintenance/dredging for navigation

Hydrology – change in land use, dams, channelization, dredging, jetties, hardening of shoreline

Agriculture, industry, housing, hydrological alteration; most of these are permanent changes. Navigation – Detroit River channel

Urbanization – affects sedimentation, hydrology, channelizations, impervious areas, groundwater recharge areas
Agriculture intensification – land use changes, increased sediment, hydrology

Invasive species
Climate change/variability/extremes
Water withdrawals/consumption

- Navigation
- Climate change
- Tributary loads
- Agriculture/irrigation
- Urbanization
- Flood control
- Recreation
- Groundwater withdrawal

Humans
Urban
Agriculture – water withdrwals, nutrients, and sediments
Withdrawals
Sewage

- Conversions of lands to agriculture/urban – impervious surfaces
- Shoreline hardening
- Water level fluctuations
- Lack of buffers in watersheds
- Increased climate variability/extreme events
- Upstream water withdrawals = change in water supply
- Nutrient loading

Urbanization, population, agriculture intensification, invasive species, climate change and variability and extremes, water supply
Urbanization – "smart" growth vs. uncontrolled – if we are going to grow in population, how to minimize impact e.g. infill, construction and development patterns
Loading – community shifts (2m) – physical? Anoxia etc.
Withdrawals and consumption

- Population growth and urban sprawl
- Agriculture intensification
- Climate change and variability
- Invasive species
- Industrial discharge
- Water withdrawal and consumption

- Physical – temperature/rate of flow = erosion = deposition = dredging

- Rapid rate of drainage of warmer water
- Filling of wetlands
- Tributary plumes – relate to agriculture
- Erosion and deposition
- Barriers – 200+ dams
- Lower groundwater tables; lower rate of recharge, reduced infiltration
- Climate change the stressor affecting water levels

- Urbanization, population growth, urban sprawl, agriculture intensification/lack of management
- Lack of buffer zones
- Climate variability/change/unpredictability
- Change in water availability for ecosystem function
- Lack of flow energy to carry sediment and flush system
- Range of natural variability of flows – deviation from "normal" and ecological boundaries
- Water takings/withdrawals
- Recreation water craft re-suspends sediment in rivers

3. Over what spatial and temporal scales do these stressors act?

Agriculture/urban – 100+ years
Climate – global
Hydrological change – 100+ years

Urban – local to regional, long term temporal
All stressors work at all scales but important to consider what scale you report on because at regional scale it may be okay but at local scale there may be serious consequences/impacts.

- Watershed/basin scale – agriculture, urbanization
- Navigation – tributary scale/seasonal/time scale
- Decades long time scale depends on the phenomena that you are observing
- Biological – yare
- Storm erosion – event
- Coastal processes – decades
- Climate change – global/decades
- Land use – basin scale/decades

All scales
Extent of shoreline hardening

Scaling
Stream morphology

All scales, depends on issue

All – especially long term and local
Integration across scales, cumulative impact

Spatial	Temporal
Lake Erie scale	Short term
Sub-watershed scale	Long term
ALL SCALES	Year to year variation
	Over decades

- Focus on local scale for effective management
- Integration across scales
- Watershed level scale

- Urban/deforestation – watershed scale
- Climate change – global and centuries
- Time scale? Decades to deforest
- Longer impact; more time to correct
- Erosion – period event or decades; days – decades (depending on issue)
- Navigation – local/tributary scale – seasonal/annual; dredging

Need to look at all scales and evaluate at all scales, local, regional, watershed, basin etc. For example, some local stressors may be very significant while at a watershed level it may not be as significant (e.g. irrigation withdrawals are a very significant local issue in the Grand River). Need to look at all spatial scales in succession to evaluate cumulative impacts.

4. What key indicators describe the physical integrity of Lake Erie and its conditions?

- Presence/quantity/health of watershed and coastal wetlands
- Stream morphology and health of riparian areas – major streams and tributaries
- Quality of lake substrates (nearshore, coastal wetlands, deep/open water)
- Local community and water infrastructure (water sources, waste water, stormwater management)

- Channel stability
- Substrate quality/quantity
- Secche
- Energy regimen

- Extent of shoreline hardening
- Stream morphology – loss of
- Kilometers of regulated river
- Habitat
- Restoration capacity
- Land use/cover
- Ratio of wetland/watershed

Shoreline development - indicate urbanization, habitat loss, sedimentation etc.; measurable, low cost, accessible
Sediment – hard to measure, perhaps turbidity is an easy substitute
Temperature – generally always measured, but never related to anything eles or observed for trends
Number of extreme event

- % natural cover
- nutrient consumption and diversion
- % impervious on recharge areas
- % riparian – tributaries and shoreline
- wetlands loss
- % of shoreline hardening – tributary turbidity
- duration of ice cover
- frequency of extreme events

- Extent of shoreline hardening – gets a lot: habitat loss. Change in sediment transport, level of development
- Land cover conversion
- Sediment loadings
- Extent of dead zone
- Extent of ice cover/extreme events i.e. climate change

- Extent of shoreline hardening
- Extent of 2m colonization
- Land cover patterns e.g. % agriculture, % impervious etc.; satellite GIS
- Sediment loadings to coastal wetlands
- In stream sediment loadings
- Extent of the dead zone
- SST and land surface temperature

- Climate change – frequency of extreme events
- Consumption and withdrawal

- Extent of shoreline hardening
- Land use – land cover
- Simple temperature measurements (lakes, rivers, tributaries)
- Frequency of extreme events
- Consumptive water use and diversions

- Temperature
- DO
- Turbidity

- Kilometers of regulated river flow (e.g. Grand River)
- Shoreline hardening
- Sediment fractionation
- Land use/cover – satellite imagery/remote sensing
- Statistics Canada data e.g. census of ag. database, conservation practices survey
- Temperature monitoring
- Frequency of extreme events
- Deviation from normal range of flows
- % farmed area tile drained
- % land cover in sensitive watershed landscapes e.g. recharge areas

5. **How do we integrate physical integrity into landscape/watershed assessments (tool availability/development)?**

Satellite imagery becoming less expensive with time/orthophotography/ remote sensing/assessments of land cover. Have part of "state" reporting processes.

6. **What are the data/information needs/gaps necessary to develop and implement these indicators?**

Where are sensitive groundwater exchange areas – protect critical functions.

- Need long term comprehensive monitoring programs
- Real commitment of government funds; long term input not one time funding inputs

Better database integration across disciplines and agencies
Database quality control; develop better remote sensing technologies